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STUDIES ON THE ASEPTIC END-TO-END ANASTOMOSIS OF THE INTESTINE

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For many years attempts have been made by surgeons to devise practical methods for the end-to-end anastomosis of the intestine which would minimize the amount of soiling of the suture line and of the neighboring abdominal structures. As a result, a number of interesting suggestions have been made by Pochhammer,[1] Werelius,[2] Flint,[3] Rostowzew,[4] Moszkowicz,[5] Gudin,[6] Wullstein,[7] and by others. The methods to which the best clinical results have been ascribed, however, have all made use of instruments, all or some of which had to be extricated from the line of closure in the concluding steps of the operations. Such procedures, of course, either leave the lumen temporarily occluded with crushed bowel, or expose the line of anastomosis to soiling from within.

A short time back Professor Halsted[8] suggested the bulkhead suture for this purpose—a procedure which was altogether novel at the time, and which afforded certain distinct advantages over the methods then in use. He demonstrated on dogs that a successful end-to-end anastomosis of the intestine might be carried out in an aseptic manner, "except as contamination may occur from stitches which of necessity or by accident have been carried into the lumen of the intestine." Until some substitute is discovered for the needle and thread it will be necessary always to reckon with this source of contamination. The fact, however, that with care the operator may prevent most or all of the stitches from entering the lumen greatly lessens the importance of this factor.

The experiences presented in this report were encountered in the course of some experiments with this method conducted on dogs. Although the procedure described here differs from that used by Professor Halsted in certain details, it nevertheless makes use of the characteristic feature of the bulkhead suture, namely, the invagination of the closed ends of the intestine with subsequent cauterization of them to re-establish the lumen. The wire-release ligature and the fibrin bolus have been substituted for the cones of paper.

The absence of any recorded microscopical examination of intestinal anastomoses made with the bulkhead suture suggested to the author the desirability of comparing the rate of healing in such anastomoses with that occurring in the simple, open, end-to-end unions of the bowel. Such a study, it was thought, would also afford some opportunity to observe the effects of the use of the cautery on the rate of healing in intestinal wounds.

METHODS

The Fibrin Bolus and the Wire-Release Ligature.—The fibrin bolus is prepared from ordinary blood fibrin after a method developed by Dr. S. Harvey,[9] of Boston. In a former communication,[10] I suggested the use of fibrin for controlling the extensive hemorrhage which sometimes follows the removal of a cerebral tumor having deep or extensive attachments to a neighboring sinus. Harvey subsequently

devised a method by which microscopic films of this material might be used for hemostasis.

The washed fibrin obtained from whipping freshly drawn blood at the abattoir is ground up to a fine pulp. This pulp is then made into sheets of any desired thickness by drying a layer in a high-power press. A sheet of this material is cut into small rectangular pieces of such a size that two or three will just occlude the lumen of the canine gut. To engage the ligature a shallow notch is made in each a few millimeters from one end.

These blocks stand steam sterilization well, retaining their shape and firm consistency. In a flask stopped with cotton they may be preserved indefinitely. Since they are digestible —in the course of several days or a week—they do not act as real foreign bodies in the alimentary tract.

The wire-release ligature is a simple contrivance which may be prepared rapidly at the table from the ordinary supplies of the operating room. Two lengths (each of about 14 inches) of extra heavy silk are used. Each is doubled once at its middle, and the folded ends of the two are interlocked over the end of a fine piece of wire, such as is used as a stilette in a large hypodermic needle (see Fig. 5). When the ends are drawn taut the threads bind the wire, and they may be tied around the bowel and bolus with a considerable degree of tension.

To release the ligature the bowel is gently supported over the region of the knot. The wire is then twisted a little back and forth in its longitudinal axis while traction is made upon it away from the gut. The thread ends now fall apart. The wire may be removed in this fashion without causing any trauma to the intestinal wall. As the bulkhead occupies the bowel immediately subjacent to the ligature there is no question of leaving the lumen occluded.

The Operative Technique.—The first step in the operation is identical with that described by Professor Halsted (Fig. 1). At the point of election the peritoneal and muscular coats are divided and stripped back on the submucosa far enough to enable the operator to place two ligatures around the gut. The intervening submucosa and mucosa are then divided with the cautery.

To prepare the bulkhead two or three of the fibrin blocks (depending upon the size of the lumen and the dimensions of the blocks) are held together and pressed against the cauterized end of the bowel invaginating it to the desired extent (Fig. 2). It saves time in the subsequent steps of the operation when the blocks are invaginated so that their exposed ends lie a few millimeters within the folded margins of the bowel. The wire-release ligature is now tied with force a short distance from the end of the intestine, binding the gut to the enclosed bolus. It is so placed that the free end of the wire is directed away from the line of anastomosis. After both pieces of intestine have been prepared in this way, the folded ends are cut away with the cautery-knife close to the ligatures, as in the Halsted method (Fig. 3).

As the vessels have not been disturbed in these steps the blood supply remains perfect up to the site of each ligature. Exactly at this line the vessels entering the gut are ligated. The larger vessels distal to this point are then also secured with circumvection ligatures. The end-to-end anastomosis now remains to be made with the continuous mattress suture (Fig. 4). An additional mattress stitch placed about each release wire is drawn tight only when the latter is removed. The wires in the course of the anastomosis find their points of exit without interfering with the approximation of the bowel ends.

The ligature about each bulkhead having been released by the withdrawal of the wire, the line of union is gently rolled in a piece of gauze to loosen the boli. With slight pressure the invagination bulkheads are liberated and the lumen of the bowel is re-established.

OBSERVATIONS

The Operative Results.—The operation as described here was performed on 37 dogs—34 times on the small intestine and three times on the colon. The specimens were removed at varying postoperative periods ranging from 48 hours to 106 days. In the series of 37 animals there were two deaths directly attributable to the work on the intestines. Postmortem examination in both instances disclosed a general peritonitis, the origin of which could be traced to a perforation in the line of anastomosis. Each of these animals, however, was quite small, with a bowel proportionately narrow in its diameter.

Two great principles are now recognized in intestinal surgery. The first, inculcated by Lembert,[11] is to rely on the serous coat to procure early and permanent adhesions; and the second, pointed out by Dr. Halsted, is to include some of the submucosa in the sutures, since the submucosa is the strongest coat of the bowel wall. Where the intestine is very small, as in the two animals just referred to, it is difficult to secure the proper approximation of the serous coats, because the inversion of any appreciable amount of bowel usually results in an occlusion of the intestinal lumen. A weak serous apposition, of course, predisposes the part to subsequent leakage. This is particularly the case where there is some encroachment upon the intestinal canal, since the latter condition always leads to more or less stasis in the proximal segment.

In larger animals very little difficulty of this nature is encountered. Human bowel should be still more favorable for this type of anastomosis, because the width of the intestine is greater and there is more of a difference in the ratio of the diameter of the gut to the diameter of its lumen.

To make the method applicable to the human colon it would be necessary to devise certain modifications of the fibrin bolus. The diameter of the bolus would have to be greatly increased, since the diameter of the canal at the line of anastomosis in the bulkhead suture is determined, in a large measure, by the dimensions of the supporting framework—the paper cone or the blocks of fibrin.

In the course of some work with the large intestine of the pig, procured from the abattoir, it was found that a bolus of

ample proportions might be constructed from fibrin by fastening together a considerable number of small blocks with a wire-release ligature. After such a support has been secured in the bulkhead by means of the usual release ligature placed around the gut, the wire of the bolus may be withdrawn, leaving the fibrin blocks secured only by the external tie. The release of the invaginated bowel ends, subsequent to the anastomosis, ultimately permits the pieces of fibrin to separate. In this form they should be well cared for by the intestine.

The modified Halsted suture suggested in this report represents, then, a practical technique for the aseptic end-to-end anastomosis of the small intestine, since all of the materials may be sterilized readily and since the experimental work has shown that a dog's life is not greatly endangered by the operation. The technique is suggested, however, solely as a step toward the solution of the problems connected with the anastomosis of the large intestine. It is in operating upon the colon, of course, that the greatest danger of peritoneal infection arises. Experiments on the living animal having to do with a colon of the human type could be carried out only in the larger animals, such as the pig or the sheep.

The Healing of the Bulkhead Anastomoses.—During the course of the first few hours subsequent to the operation the serous surfaces become glued together with a fibrinous exudate. This exudate, as Halsted [13] and Mall [18] first pointed out, appears even before the anastomosis is completed, and serves to seal the stitch holes. Evidences of a reaction on the part of the tissues to the trauma sustained during the operation now make their appearance in the form of edema, infarct formation, leucocytic infiltration, etc.

All of the specimens of 48 hours show comparatively large flaps of inverted bowel wall—an inherent feature of the bulkhead method. These inturns, however, are not all of the same size, but vary somewhat from animal to animal. The largest of all was present in an anastomosis which had been made, for comparative purposes, with a knife instead of a cautery. The other steps of the bulkhead operation had been carried out as usual.

At the end of two days the condition of the inturn depends upon the condition of its vessels and upon the amount of injury to which it was subjected. When through either or both of these factors the viability of the inverted tissues has been seriously affected, a slough starts to form which varies in extent throughout the circumference of the bowel. The rapidity with which the slough separates and the mucosa covers the ulcer depends, of course, upon the extent of the necrosis. It is this factor, namely, this extent of the slough, which chiefly influences the rate of healing. Of much less significance in this respect is the size of the inturn.

At 48 hours (Fig. 6) the inverted bowel wall is edematous and hemorrhagic, and at the base of the flaps there are changes suggesting necrosis, particularly of the epithelium. The muscularis mucosæ on either side can be traced out to the end of the inturn, but it soon appears edematous. A corresponding swelling is evident in the submucosa. Shortly beyond the base of the inturn the muscle coats become hemorrhagic, swollen and infiltrated with leucocytes. At the suture line, extending up between the serous surfaces of the bowel ends to the level of the muscularis mucosæ, is seen the fibrinous exudate. This serves to smooth over the external surface of the anastomosis.

Sections from certain other 48-hour specimens show a less extensive sloughing of the inverted parts. As a rule, the inturned ends are about equally affected. Occasionally, however, owing to poor approximation of the segments or to extensive unilateral necrosis, the two flaps may be of very unequal length. When the flaps are of unequal length there is, of course, a great delay in the process of healing, especially of the mucosa. In the instances in which the knife was substituted for the cautery there is again a variation in the picture from specimen to specimen. It is this variation which makes it difficult to estimate the effects of the cautery on the process of healing. On the whole, there seems to be very little difference between the two sets of specimens.

At seven days (Fig. 9) the stage of sloughing has passed and the process of repair is fairly under way. The inturn is now surmounted by an ulcer, the bed of which consists of partially organized exudate. Quantities of polymorphonuclear leucocytes and round cells are present together with many young connective-tissue cells and newly formed blood-vessels. At the borders of the ulcer the epithelium is low and undifferentiated in type. Villi are found only at some distance from the uncovered area. The stratum fibrosum is visible on the left up to the edge of the mucous membrane. Here it lies exposed. On the right side the end of the stratum fibrosum is covered by the flattened epithelium. The muscularis mucosæ has a fairly normal appearance up to the region where the epithelium becomes embryonic in type. Its identity is then lost in the scar tissue. The submucosa on one side is considerably thickened; both of the layers, moreover, are denser than usual, owing to the presence of new connective-tissue cells and young blood-vessels. A very appreciable amount of new fibrous tissue is scattered throughout the muscle bundles of the inturn. The muscle layers are also infiltrated with white blood-cells in places, the reaction assuming its greatest proportions in the immediate vicinity of the stitches. This picture is very similar to Gould's [14] 5-day stage (plain end-to-end anastomosis of the intestine), to Halsted and Mall's [13] 6-day specimen (entero-enterostomy), and to Flint's [15] 7-day suture (gastro-enterostomy).

A section from another part of the same specimen shows a much more advanced stage of healing. Here the mucosa has practically covered in the ulcer. The epithelium over the exudate is of the low, undifferentiated type, containing a few shallow crypts, but no villi. The stratum fibrosum and muscularis mucosæ may be traced up to within a very short distance of the line of union of the epithelial layers. They now extend, accordingly, a little beyond the region where the villi disappear. Toward the base of the anastomosis the muscle layers are found to be separated by a moderately broad band of scar tissue, comprising crushed muscle bundles, new connective-tissue cells, and white blood-cells. This picture closely

resembles the 24-day specimen of Halsted and Mall and the 8-day specimen of Gould.

In a section from a 14-day-old suture (Fig. 10) the ulcer is found to be converted into a mass of fibrous tissue which still shows a considerable degree of reaction; and this is completely covered by a low, atypical epithelium. Flint found little evidence of reaction at this time (14 days) save in the immediate neighborhood of the stitches. The cleft at the point of union of the two epithelial coats is sheathed by a single layer of low columnar cells. The stratum fibrosum does not completely bridge the scar tissue. Traces of fibers suggesting the muscularis mucosæ are visible on one side up to the midline. On the side of the cleft, however, this layer is indistinct for a short distance. The exudate between the deeper muscle layers has become definitely organized.

Another section from this specimen shows a somewhat less advanced stage of healing. Here a very narrow ulcer caps the inturn. Muscle fibers, apparently from the deeper layers, are found scattered in the gap between the ends of the muscularis mucosæ. This corresponds to a 14-day specimen described by Flint in which the muscularis mucosæ had partially regenerated from each side, the intervening defect being filled in by muscle from the circular and longitudinal layers.

In a section from a 14-day plain end-to-end suture the picture is fairly similar, except that in this instance there is less of a diaphragm. The ulcer is covered at the center by a single layer of epithelial cells. The muscularis mucosæ and the stratum fibrosum here disappear close to the edges of the ulcer—rather far from the midline. Gould's 14-day specimen shows an inturn fully as large as that seen in the 14-day bulkhead suture (Fig. 10).

How greatly the repair of the intestinal coats may be delayed by an inequality of the sloughing process in the two halves of the inturn is indicated by the condition of a specimen which was removed at 21 days. A long, well-nourished flap remains on the left side. On the opposite side, however, no appreciable trace remains of the inverted bowel wall. The inturn is covered on one surface by a fairly normal appearing coat of mucous membrane, but over the end and on the opposite face no epithelium is visible. So far as the function of the anastomosis is concerned the exposure of this area of granulation tissue probably has no especial significance. The line of suture, though, cannot be considered healed until the epithelial layers have united; and in a case such as this a number of additional weeks would be required to accomplish it.

An anastomosis 24 days old (Fig. 11) shows a very advanced stage of repair. In one section the ulcer is covered with a moderately high epithelium. Near the point of union some shallow crypts are visible. No villi, however, make their appearance here. The muscularis mucosæ reaches almost across the defect. In the region where the villi disappear the submucosa broadens out and merges into the scar tissue of the old ulcer. A section from another part of the circumference reveals a slight gap between the epithelial layers of either side. The muscle coats below are separated by a rather wide area of scar tissue which still presents a considerable degree of infiltration.

There is no more heaping up of the coats at the line of anastomosis in this specimen than was noted by Dr. Halsted and Dr. Mall in their intestinal suture of 24 days or by Dr. Flint in his gastro-enterostomy of 55 days. More of the bowel wall certainly is inverted in carrying out the bulkhead operation than in making a plain end-to-end anastomosis. The similarity in the specimens, then, must be due to the fact that subsequently to the former procedure most of the inturn had been cast off. From this it appears that a large inturn may not materially prolong the healing time provided that the two ends slough to about the same extent.

A section from a plain end-to-end anastomosis of 22 days' duration shows a picture little differing from this except for an absence of most of the infiltration which characterizes the bulkhead suture. The 22-day section just referred to is very similar in appearance to Mall's 24-day suture (Fig. 10).

At 41 days (Fig. 12) the epithelium completely bridges the line of union. Here short crypts are present together with comparatively large villi. Over a rather wide area no muscularis mucosæ is discernible, but where one would expect to find it connective tissue and muscle from the deeper layers appear to be aligning themselves to form a substitute. A rather wide expanse of scar tissue is present in this specimen between the ends of the muscle coats. As the bowel is comparatively flat now at the site of the anastomosis, this separation of the muscle coats suggests the fourth stage of healing—the straightening of the suture—as noted by Mall in Halsted's sutures of 25 to 36 days. The process of healing in the bulkhead suture, accordingly, may, under favorable circumstances, lag but little behind that occurring in the plain end-to-end anastomosis.

Sections from a 50-day specimen are quite similar in appearance. A somewhat more advanced state of repair is seen in a 52-day plain end-to-end suture. The epithelium is of normal height throughout and the circular muscle coats are well approximated. There is only a very narrow break between the ends of the muscularis mucosæ.

From this period on, the villi and crypts at the anastomosis gradually assume more normal proportions. As the submucosa decreases in width the muscularis mucosæ become regenerated across the defect. The ends of the muscle coats at the same time approach each other and become bound together by a very narrow scar. The subserous scar slowly disappears (Figs. 13 to 15).

The rate of healing described above, however, is not characteristic of all bulkhead sutures, as has been emphasized before. Owing probably to the necessity of an extensive repair, the regeneration in certain places is considerably retarded. In a 57-day specimen one section shows an extremely narrow ulcer still existing at the line of union. Another section has a single layer of epithelial cells covering this site. The other coats are all well healed. A rather prominent inturn remains still in a 77-day suture. The presence of the inturn, however, has not interfered with the regeneration of the coats.

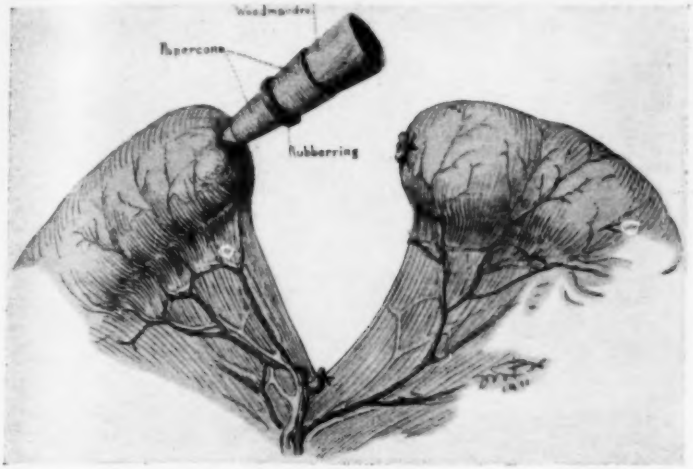

FIG. 1.—The Halsted bulkhead suture. One of the ends of the divided intestine is being invaginated by the wooden mandrel which carries the paper cone.

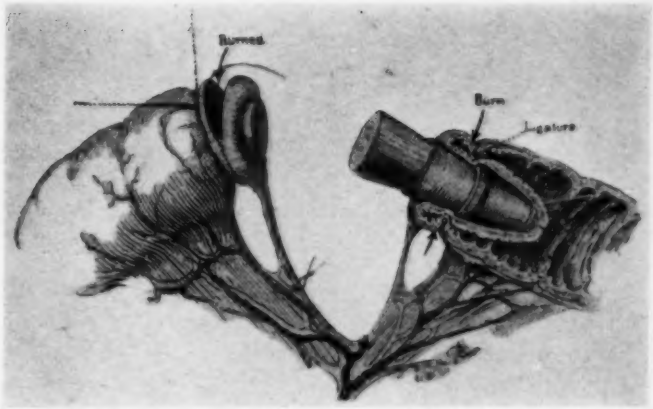

FIG. 2.—The Halsted bulkhead suture. On one side the intestine has been partially burned through by the cautery knife.

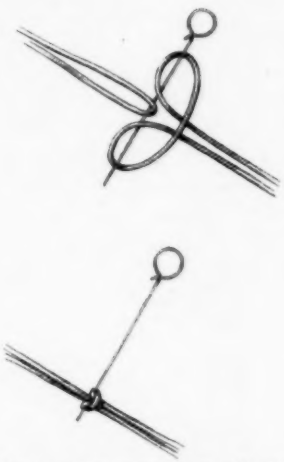

FIG. 5.—The wire-release ligature. Having invaginated the end of the intestine with the fibrin bolus (instead of the wooden mandrel carrying a paper cone—see Fig. 2) the operator ties the wire-release ligature securely about the bowel to anchor the bulkhead.

FIG. 3.—The Halsted bulkhead suture. The ends of the intestine and the paper cones, having been divided with the cautery knife, are apposed, the invagination bulkheads being held firmly in place by the encircling ligatures.

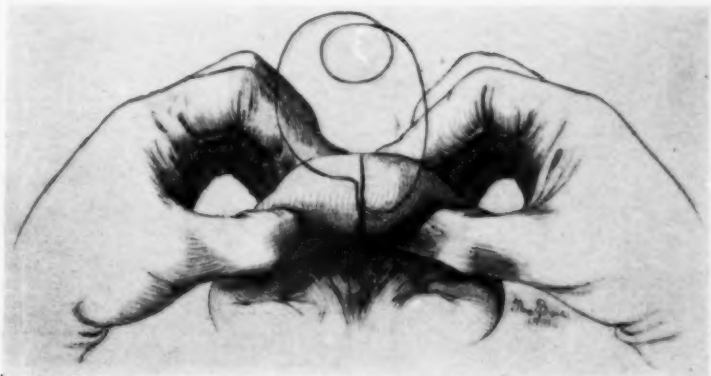

FIG. 4.—The Halsted bulkhead suture. The fingers of an assistant are producing a slight additional invagination to eliminate the danger of engaging the invaginated bowel in the suture.

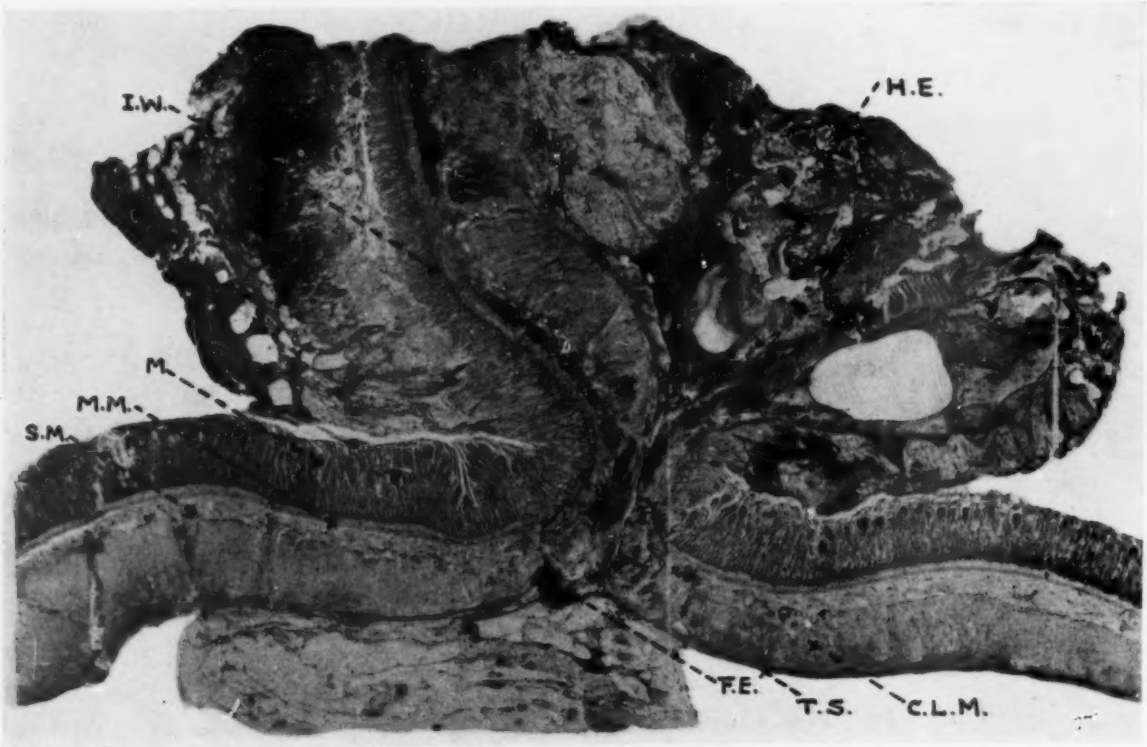

FIG. 6.—Section of end-to-end intestinal anastomosis. Modified bulkhead method (wire-release ligature and fibrin bolus) of 48 hours. I. W., invaginated bowel wall; H. E., hemorrhagic exudate; M., mucosa; M. M., muscularis mucosæ; C. L. M., circular and longitudinal muscle layers; T. S., tunica serosa; F. E., fibrinoplastic exudate.

FIG. 7.—Bulkhead suture (wire-release ligature and fibrin bolus) of 72 hours. S., stitch; N. I., necrosis of inturn.

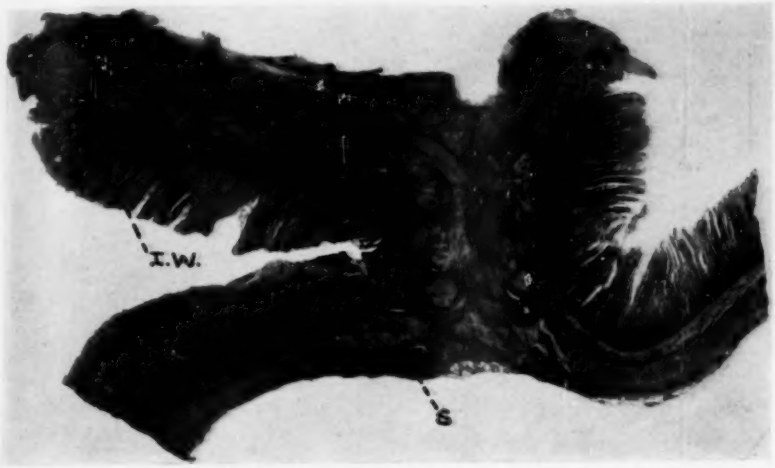

FIG. 8.—Bulkhead suture (wire-release ligature and fibrin bolus) of 5 days. S., stitch; I. W., unusually well-nourished inturn.

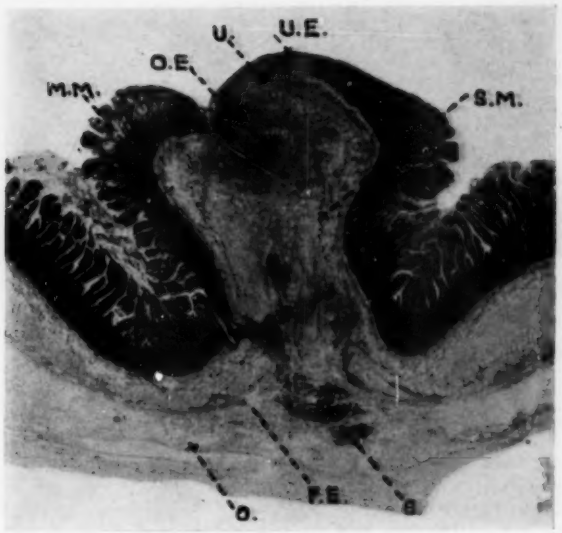

FIG. 9.—Bulkhead suture (wire-release ligature and fibrin bolus) of 7 days. U., ulcer; O. E., organizing exudate; U. E., undifferentiated epithelium; M. M., muscularis mucosæ; S. M., submucosa; F. E., organizing fibrinoplastic exudate; O., omentum; S., stitch.

FIG. 11.—Bulkhead suture (wire-release ligature and fibrin bolus) of 24 days. U., ulcer capped by moderately high epithelium; F. E., scar tissue between muscle coats still showing many leucocytes; inturn has almost disappeared.

FIG. 10.—Bulkhead suture (wire-release ligature and fibrin bolus) of 14 days. U., ulcer covered by low, undifferentiated epithelium; F. E., organized exudate between muscle coats.

FIG. 12.—Bulkhead suture (wire-release ligature and fibrin bolus) of 41 days. L. U., line of union of muscle coats; Sc., wide scar between muscle coats due to "straightening of the suture."

FIG. 13.—Bulkhead suture (wire-release ligature and fibrin bolus) of 63 days. L. U., line of union of mucous coats; M. C., muscle coats more closely approximated; Sc., scar tissue disappearing.

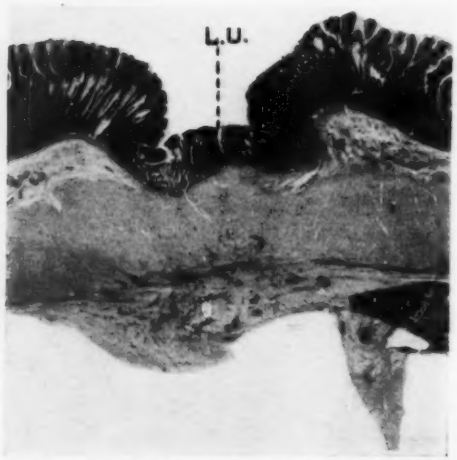

FIG. 14.—Bulkhead suture (wire-release ligature and fibrin bolus) of 79 days. L. U., line of union of the coats.

FIG. 15.—Bulkhead suture (wire-release ligature and fibrin bolus) of 97 days. L. U., line of union of the coats. The dark stippling at *A* is due to sublimate precipitate.

The rate of repair does not appear to be greatly influenced by the use of the cautery. In some of the earlier stages no appreciable difference was noted in this respect between the bulkhead sutures divided with the knife and those treated with the hot iron. Similar observations have been made by Scudder and Harvey[16] in their study of the use of the cautery in the treatment of gastric ulcers. At 105 days a suture in which the cautery-iron was used shows a slightly better regeneration of the mucous coat than a suture of 106 days in which the knife was substituted for it.

SUMMARY AND CONCLUSIONS

This report is based upon the results obtained from using the bulkhead suture (Halsted) in 37 dogs. A new wire-release ligature and a bolus of fibrin which is easily sterilized have been substituted for the paper cones. Specimens were secured following the operations at intervals varying from a few hours to 106 days. A study of the process of healing shows the following points:

The process of repair in the bulkhead suture may, under favorable circumstances, lag but little behind that noted in the plain end-to-end anastomosis. On the average, however, the healing is a little slower in the former.

A large inturn may not materially lengthen the period of regeneration, provided that the two inverted bowel ends remain about equal in size. The size of the inturn remaining after several weeks varies greatly from specimen to specimen. Frequently very little inverted bowel is found at this time.

As a rule, there is a considerable delay in the repair of the mucosa when the two parts of the inturn are of unequal length—owing to poor approximation or to an inequality in the necrosis on the two sides. This, however, does not appear to affect the function of the intestine.

No striking difference was noted in the rate of repair between bulkhead sutures in which the cautery had been used and those in which the knife had been substituted for it.

Stitches which puncture the epithelium usually delay the healing of the latter. Frequently such sutures carry a prolongation of the epithelium down into the deeper layers. Such adenoma-like prolongations may weaken the line of union where only one layer of stitches has been inserted.

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ANOMALIES OF THE PULMONARY VEINS

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(Anatomical Laboratory of The Johns Hopkins University, 1918)

Although anomalies of the pulmonary vascular system are by no means uncommon, the following three cases, met with during the course of dissection in the anatomical laboratory of the Johns Hopkins Medical School (1917-18), are so exceptional as to merit special mention, particularly in view of their possible embryological explanation. In two of the dissections the upper pulmonary vein of the left side opened into the left innominate vein; in the third case the upper pulmonary vein of the right side emptied into the superior vena cava.

In the first case, which is shown in Fig. 2, the left superior pulmonary vein passes through the hilum of the lung above the pulmonary artery. It pursues a course ventrad and cephalad and opens into the left innominate vein 1.5 cm. from the juncture of the latter with the subclavian vein. It measures 3.5 cm. in length and is slightly smaller in diameter than the left inferior vein. It drained all of the upper lobe with the exception of a small area on the inferior medial surface, adjacent to the inferior lobe. This area was separated from the upper lobe by a fissure, and was at first thought to be a separate lobe. It had its own bronchus, its separate arterial branch and its own vein from the inferior pulmonary vein. However, the fissure proved to be entirely superficial and the separated area to be part of the upper lobe.

The vessels in the hilum of the lung occupy abnormal positions. The upper pulmonary vein lies above the pulmonary artery; below this is the bronchus, and below this, again, is the

inferior pulmonary vein. The last enters the left auricle in the normal way. As the veins from the right lung are normal, only three veins enter the left auricle.

The heart presents several peculiarities, the most noticeable being the relatively great size of the pulmonary artery. In view of the greater amount of blood it received, one would expect to find the entire right side of the heart enlarged, and the left side smaller in order to establish an equilibrium. This appeared to be the case, though it cannot be stated definitely, because in a preserved heart such as this exact measurements cannot be made.

The interventricular septum lies farther to the left than is apparent in Fig. 2. A notch in the lower border of the anterior wall of the right ventricle gives this false impression. The notch seemed to have no significance at all in the interior of the heart. One thing of importance, bearing directly as it does upon the discussion to follow, is the total lack of any left oblique vein of the heart.

The second case dissected is analogous to the one above described. In this the left upper pulmonary vein opens into the left innominate, and is thought to have drained the whole of the upper lobe, though its exact distribution was not ascertained at dissection.

In the third case which is shown in Fig. 3, the right upper pulmonary vein opens into the superior vena cava, near the opening of the azygos, and 1.5 cm. from the juncture of the innominate veins. As in the second case, its exact distribution was not observable at dissection, though it was thought to have drained the entire upper lobe. The only other peculiarity noted was in the heart; here the orifice of the coronary sinus was located on the same side of the Eustachian valve as the inferior vena cava.

Report of various other cases of anomalous pulmonary veins have been published. Those in which there has been a communication between the pulmonary and systemic systems may be classified as follows:

Four with the Left Innominate Vein

Two cases. Upper pulmonary vein of the left side opening into the innominate.
Thane, C. D., Jour. Anat. & Physiol., 1906, xl.
Bachhammer (by Debierre), Traité d' anatomie humaine, 1890, t. 2.

One case. Additional pulmonary vein draining half of the upper lobe of the left side, opening into the innominate.
Looten, J., & Ruyssen, G., Biblio. anat., 1910, xx.

One case. Vein draining upper two-thirds of the left lung into the innominate, with a branch to the accessory hemiazygos.
Patterson, J., Jour. Am. Med. Assn., 1913, lxi.

Six with the Superior Vena Cava

Five cases. Upper pulmonary vein of the right side into the superior vena cava.
Grueber (2 cases), Arch. path. Anat., 1876.
Meckel, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.
Gegenbauer, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.
Winslow, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

One case. Left pulmonary vein into the superior vena cava.
Weber, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

Three with the Inferior Vena Cava

Two cases. Upper right pulmonary vein into the inferior vena cava.
Brown, A. G., Anat. Record, 1913, vii.
Chassinat, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

One case. Five or six small upper left pulmonary veins into a small rudimentary vena cava.
Hyrtle, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

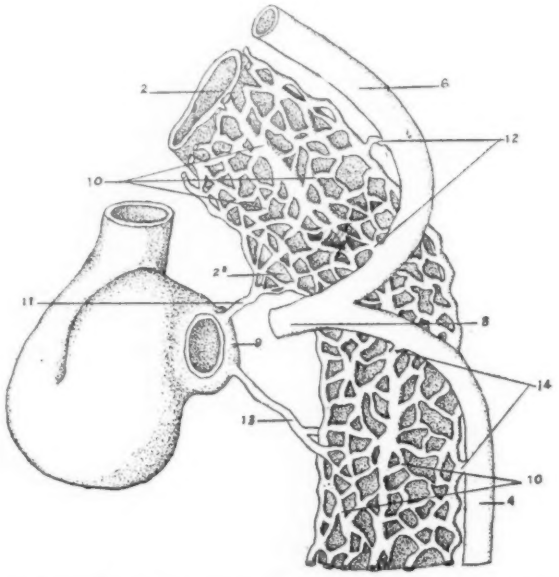

Fig. 1.—Reconstruction of a 4.5 mm. cat embryo. The left cornu of the sinus venosus has been removed.

2. Intestinal tract.
2a. Pulmonary anlage.
4. Left postcardinal vein.
6. Left precardinal vein.
8. Left duct of Cuvier.
9. Sinus venosus.
10. Splanchnic plexus.
11. Cephalic communication of the splanchnic plexus with the cephalomesial portion of the sinus venosus (common pulmonary vein).
12. Communication between the splanchnic plexus and precardinal vein.
13. Caudal communication of the splanchnic plexus.
14. Communication between the splanchnic plexus and the postcardinal vein.

One with the Azygos Vein

One case. Single right pulmonary vein into a large azygos vein.
Sheperd, F. J., Jour. Anat., XXIV.

Two with the Subclavian Vein

Two cases. Left pulmonary vein into the subclavian vein.
Weber, Arch. Anat. u. Physiol., Leipzig, 1829.
Ramsbotham, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

Communications between the pulmonary and portal systems are exceedingly rare, only two cases being found in the literature.

Two with the Portal Vein

One case. Right pulmonary vein into the portal vein while the left pulmonary vein opened into the subclavian vein.
Ramsbotham, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

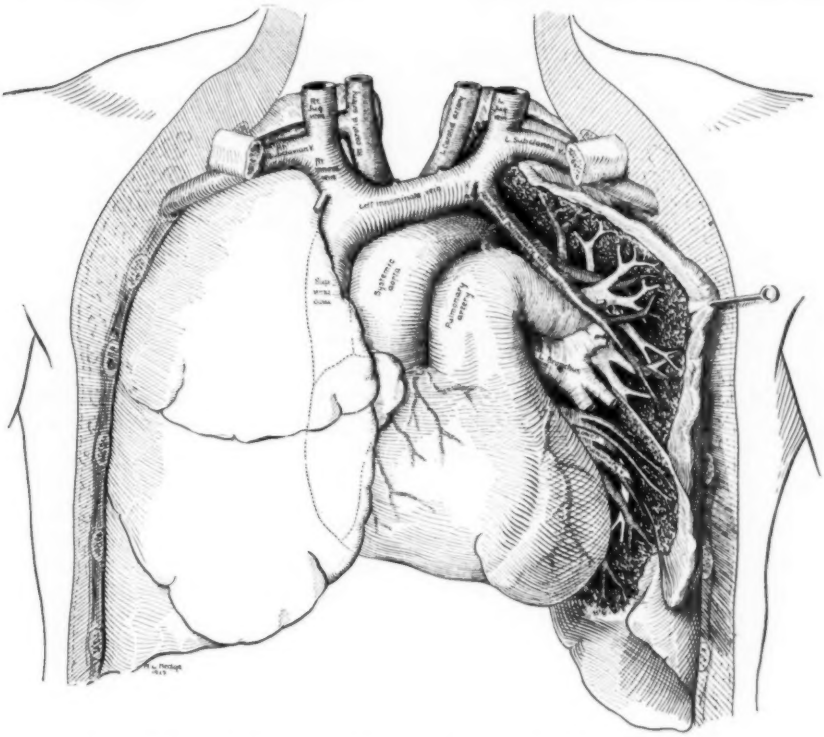

FIG. 2.—Case I in which the upper left pulmonary vein empties into the left innominate vein, 1.5 cm. from the junction of the latter with the subclavian vein. This abnormal pulmonary vein drained all the upper lobe of the lung with the exception of a small area adjacent to the lower lobe. This area was drained by a branch of the inferior vein and, as can be seen in the figure, was separated from the rest of the upper lobe by a shallow fissure. It was supplied by a separate branch of the pulmonary artery and a separate bronchus. There were but three pulmonary veins opening into the left auricle. The pulmonary artery is seen to be exceptionally large. A notch in the lower border of the anterior wall of the right ventricle gives a false impression as to the position of the interventricular septum. This lies further to the right than appears in the figure. The left oblique vein was entirely lacking. Case two was analgous to this one.

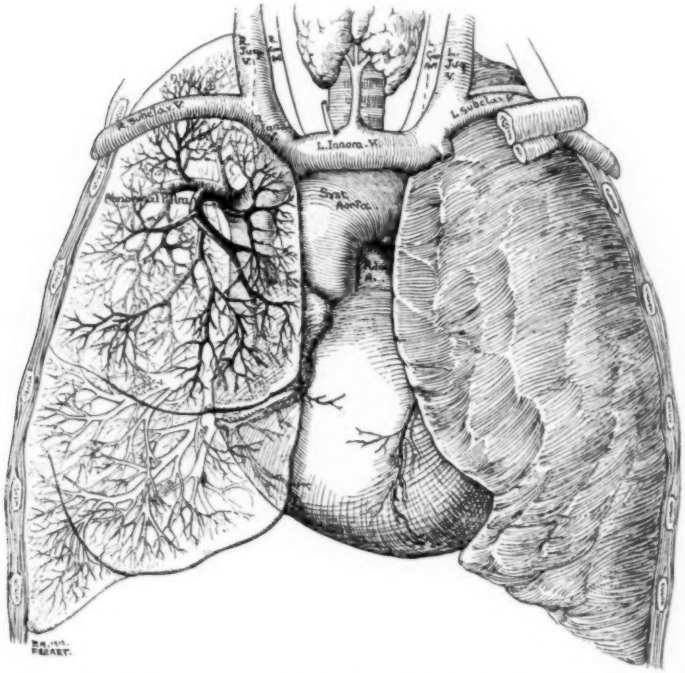

FIG. 3.—Case III in which the upper right pulmonary vein empties into the superior vena cava, 1.5 cm. from the junction of the innominate veins. It was thought to have drained all of the upper lobe though its exact distribution was not ascertained in dissection. All the other structures were normal with the exception of the orifice of the coronary sinus which is located on the same side of the Eustachian valve as the inferior vena cava.

One case. Communication between a pulmonary vein and the portal vein by a branch perforating the diaphragm and going to the hilum of the liver in a child of 15 days.

Arnold, *In* Poirier & Charpy's Traité d'anatomie humaine, 1901, t. 2.

Such anomalies of the pulmonary veins have been explained by Brown ('13), on the basis of an anastomosis between the capillary plexuses in the embryo. He followed out the development in the domestic cat and supplemented this with the work of A. M. Miller on the chick.

In cat embryos of 4.5 mm., Brown describes a net-like capillary plexus in the mesenchyme surrounding the whole length of the intestinal tract. This plexus, which he designates the "splanchnic plexus" (Fig. 1), anastomoses freely with the adjacent veins of the systemic circulation. The cephalic part of the plexus anastomoses with the capillaries around the aorta, and with the precardinal and segmental veins; the caudal part, with the omphalo-mesenteric and postcardinal veins. In addition to these communications there are two constant connections with the venous end of the heart, a cephalic or pulmonary, and a caudal or postcaval.

As the pulmonary anlage grows out from the intestinal tract it pushes before it the surrounding part of the splanchnic plexus. The capillaries of the two sides fuse into a common stem at the ventral pole of the anlage. This common stem, the anlage of the pulmonary vein, proceeds ventrally and somewhat caudally, to open into the sinus venosus, between and slightly dorsal to the ducts of Cuvier.

Flint (1907) takes the opposite view for the formation of the pulmonary vein. In the pig embryo he describes it as growing out from the sinus venosus and passing dorsally through the dorsal mesocardium to the pulmonary anlage. There it anastomoses with the plexus around the pulmonary anlage and the intestinal tract, though how this is accomplished he does not show.

Likewise, Federow (1910) describes the pulmonary vein as an outgrowth of the dorsal wall of the sinus venosus, for the amphibian, reptile, bird and mammal. He describes the cavity of the sinus as evaginating into a proliferation of the endothelium on the posterior wall of the sinus venosus, and at a later stage as connecting with the capillaries around the pulmonary anlage.

The splanchnic plexus, described by Brown, forms longitudinal drainage lines along the lateral and dorsal sides of the intestinal tract. At the level at which the sinusoids of the liver are forming, branches of the lateral longitudinal drainage lines fuse in the median plane into a single vessel, which passes cephalad through the dorsal mesocardium to the sinus venosus. This opens into the caudal part of the sinus venosus between the omphalo-mesenteric veins opposite the opening of the vein from the pulmonary anlage. At a somewhat later stage Brown recognizes in this the anlage of the hepatic and suprahepatic portions of the postcava.

This point seems to be somewhat confused. The hepatic and suprahepatic portions of the postcava or inferior vena cava, as described by Sabin (1915) for the pig, are derived from the omphalo-mesenteric veins and certain hepatic sinusoids. This is the case for man also, as described by His (quoted by Mall, 1905). However, though Brown may have confused the development of the inferior vena cava, the communication between the splanchnic plexus and inferior vena cava would still hold good. Where the inferior vena cava—the portion from the mesial cardinal veins—curves ventralward toward the liver, Sabin (1915) describes a branch passing forward into the mesentery in the same dorsal position, to anastomose with the esophageal plexus just below the bifurcation of the trachea. On the left side a similar branch passes forward from the point of union of the two mesial cardinal veins to anastomose with the esophageal plexus.

These various anastomoses explain the anomalies of the pulmonary vein, being for the most part the persistence and an enlargement of one of these several communications which are found in the embryo and which ordinarily atrophy. The persistence of the communication between the pulmonary vein and the precardinal veins by way of the splanchnic plexus would explain the communication between an adult pulmonary vein and the innominate veins or the superior vena cava. Likewise, the persistence of the connection between the pulmonary vein and the esophageal plexus, and its connection with the developing inferior vena cava, would account for such a condition as was found in the several cases cited, where one of the pulmonary veins opened into the inferior vena cava. With the enlargement of one of the bronchial veins whose development is observed in slightly later stages, the connection between the pulmonary vein and the azygos or hemiazygos will be understood. The anastomosis between the splanchnic plexus and the omphalo-mesenteric veins is probably the cause of the few cases reported in which there was a communication between the pulmonary and portal systems. As the common stem from which the pulmonary veins develop is absorbed by the sinus venosus, its arrest at any stage would lead to a variation in the number of pulmonary veins found in the adult.

Brown shows how the pulmonary vein, which in an embryo 4.5 mm. long opens into the sinus venosus in the median plane, finally comes to empty into the left auricle. Between this and the 5 to 6 mm. stage a change takes place in the position of the sinus venosus in relation to the left auricle so that the orifice of the pulmonary vein opens to the left of the left sinus valve. The sinus moves caudalward and its lower portion shifts to the right side. The right duct of Cuvier is short and empties into the right cornu of the sinus; the left duct is longer and passes caudalward and to the right, to empty into the left cornu which joins the left part of the right cornu. The two cornua then open into the caudal and right aspect of the common auricle by a single orifice. With the subsequent formation of the right and left valves of the sinus, the orifice of the pulmonary vein, which has kept its relatively median position in the cephalic part of the sinus, comes to lie between the left valve of the sinus and the atrial septum (septum superius or primum) which is beginning to develop.

At a slightly later stage (6.5 to 7 mm.), the orifice of the pulmonary vein attains its permanent position in the left

auricle. This is brought about by changes which divide the heart into its several compartments. The cephalic part of the right valve of the sinus and the septum spurium, shift to the left and fuse with the atrial septum. The left valve of the sinus also moves to the left, its cephalic portion uniting with the dorso-caudal portion of the atrial septum. The orifice of the pulmonary vein precedes the left valve of the sinus and passes in under the atrial septum. With the formation of the auricular septum, the orifice lies in the left auricle and thus the pulmonary vein attains its permanent position.

The plexus around the pulmonary anlage has also undergone accompanying changes. Ventrally it is drained by the pulmonary vein; dorsally, communication has been established with the azygos and the hemiazygos by way of the plexus around the esophagus. This communication represents the future bronchial veins. The broncho-pulmonary anastomoses in the lung bud itself are apparent. The communication between the pulmonary plexus and the inferior vena cava by way of the esophageal plexus is only temporary. With further development, the plexus surrounding the pulmonary anlage loses its connection with the esophageal plexus and subsequently with the systemic veins, except for the bronchial veins and for occasional small veins.

In the two cases under consideration in which the upper left pulmonary vein empties into the left innominate, in terms of the above explanation, we have a persistence of the connection between the pulmonary plexus and the precardinal vein. In the one case which was completely dissected it was a persistence of that portion of the precardinal which ordinarily becomes the left oblique vein of the heart. It will be noted from the description that this was lacking in the adult. In the third case in which the upper vein of the right side emptied into the superior vena cava, the anomaly was likewise due to the persistence of the connection between the embryonic pulmonary plexus and the precardinal vein of the right side. Why we do not get a persistence of this embryonic condition more often is impossible to explain. According to Thoma (Mall, 1905) we find that ultimately it is something inherent in the tissues themselves which determines the development of the capillaries. Anything further than this would be mere conjecture.

SUMMARY

The common pulmonary vein develops from the communication between the plexus surrounding the intestinal tract, designated by Brown as the "splanchnic plexus," and the sinus venosus. As to whether the vein is an outgrowth of the sinus venosus or whether it is derived from the plexus which is pushed forward by the developing lung bud is still a matter of dispute. The ventral and caudal portion of the plexus surrounding the lung bud is drained by the common pulmonary vein; the dorsal and cephalic portion is drained into the azygos and the hemiazygos by the future bronchial veins. The orifice of the common pulmonary vein, accompanying the unequal growth of the two halves of the sinus and auricle, empties into the sinus to the left of the left valve. The orifice precedes the shift of the left valve of the sinus to fuse with the atrial septum, passes under the latter and with the formation of the interauricular septum, empties into the left auricle.

The splanchnic plexus is connected with the adjacent capillaries and veins of the systemic and portal systems. The persistence and enlargement of any of these embryonic connections explains the various anomalies that have been found in the pulmonary veins. An investigation is now under way which it is hoped will clear up the few confused points and will show these conditions to be similar in the human embryo.

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THE RELATION OF THE SUPPLYING OVARY TO THE CAUSATION OF SEX

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"The problem of the causation of sex in mankind has always been a fascinating one, and only recently it has been described as 'on the borderland of the insoluble.'"

The above paragraph is quoted from the preface to the first edition of "The Causation of Sex in Man," by E. Rumley Dawson of London, the second edition of which has recently been published in this country by Paul B. Hoeber, New York. The principal theory advanced therein is that "the supplying ovary is in reality the essential factor in the causation of sex." This theory is so simple in its conception and so contradictory to the conclusions of recent investigators that it invites criticism.

From a careful consideration of the theories heretofore advanced concerning the causation of sex, the conviction is

obtained that sex is determined either in the germ-cells as such, or in the ovum shortly after the fusion of the male and female elements, but before segmentation occurs. The fact that in all mammalia single ovum twins are invariably of the same sex is alone sufficient proof that sex must be determined before segmentation has progressed, for this condition can result only when the first division of the fertilized egg has been so complete that two new cells are formed in which independent segmentation then proceeds. With this conviction it is not difficult to understand that all investigation of the problem, to be of value, must be based upon the study of the differences in the physiology of the reproductive organs of male and female, or upon the study of the physiology of the unsegmented fertilized ovum.

The reproductive organs of the two sexes differ so radically in function that it was not illogical that Schenk (1897) should have advanced the theory that the sex of the offspring could be influenced by the general physiology of one parent, and was determined by the state of nutrition of the female at the time of conception. In view of the occurrence of double ovum twins of different sexes, as Dawson says, the probability of such an influence is extremely unlikely. If we study the investigations which have been made upon the special physiology of the sex glands, we find that Doncaster (1914) has shown that certain species have both male and female ova, each type capable of developing by parthenogenesis; whereas, quite to the contrary, the work of Wilson (1906), Stevens (1906), Morgan (1913), and others show that in other species the sex-determining factor is present in the spermatozoa alone. In view of the evidence advanced by these workers concerning the influence in lower animals of the female element on the one hand and of the male element on the other, it seems probable that sex is determined in man before fusion of the elements. Further investigation may, however, show that one or the other element has a sex-determining property which is activated after fusion. If this should be shown it is evident that the causative factor of sex is present only in the fertilized unsegmented ovum.

It has been appreciated from earliest times that any theory of the causation of sex should be based upon physiological study. The necessity of this is realized by Dawson, and his theory depends upon the physiology of ovulation. Although termed a new theory, in its consideration one is reminded, in fact by Dawson himself, of similar theories previously advanced, particularly those of Hencke (1786) and Millot (1816). According to these male babies result from the union of ova from the right ovary with spermatozoa from the right testicle, while the union of ova and spermatozoa from the left-sided organs produces female children. The theory set forth by Dawson, that "a male fœtus is due to the fertilization of an ovum that came from the right ovary, and a female fœtus is due to the fertilization of an ovum that came from the left ovary," differs from this older one only in that "the spermatozoa do not influence sex at all." This principal theory is supplemented by another stating that the ovaries usually and normally ovulate alternately at an interval which can be determined in every woman by the length of her menstrual cycle. From these two premises Dawson deduces rules for "forecasting or predicting the sex of the unborn child, and on the determination or production of either sex at will."

Such a theory as that embodied in the first of these premises must be proven in two ways: First, by the demonstration of differences either in the ovaries or in the ova; and second, by clinical evidence.

Dawson interprets the slightly larger size of the right ovary as indicative of a special physiology for each ovary and, although histology teaches us that the tissue of the two ovaries is identical, he states that the ova in the right ovary differ from those in the left. He further attempts to prove this by reminding us that the ova of different mammalia and different races when fertilized produce only their kind, although the ova themselves do not differ in their known structure. He ascribes this "sexifying" factor to an ultramicroscopic or to a chemical property. That there may be differences in the ova of the two ovaries cannot be denied, but such differences can only be proven by work similar to that of Doncaster. Moreover, in the absence of parthenogenesis in mammalia, the chromosome theory of the causation of sex in man, advanced by Morgan and based upon the studies of von Winiwarter (1912), seems to indicate that such differences in human ova as claimed by Dawson, even if they exist, cannot be accepted as factors determining sex.

Clinically, Dawson attempts to prove that sex is determined by the ovary supplying the ovum by giving records of his own patients and by reference to cases in the literature, and, in addition thereto, by analogy from similar occurrences in domestic animals.

By direct observation of the ovaries during pregnancy or shortly after its termination the location of the corpus luteum of pregnancy can usually be ascertained. Only when this is seen macroscopically or microscopically, however, are we justified in concluding which ovary supplied the ovum fertilized. With the exception of those cases of pregnancy following the removal of an ovary, the examples given by Dawson are supposedly based upon such observations made at operation or post-mortem examination.

His cases are classified in certain obvious groups, each of which demands short comment.

Group A (Chapter VIII).—Cases of single intrauterine pregnancies can be used as conclusive proof of the theory without comment, provided the proper observations upon the location of the corpus luteum and the sex of the child have been made. In this group, also, would naturally fall cases of intrauterine multiple pregnancies. Instances of single ovum twins of known sex in which the corpus luteum is demonstrable are acceptable; while instances of double ovum twins are of doubtful value as confirmatory evidence. In the latter group there are six possible combinations of the location of the corpora lutea and the sex of the twins: (1) Different sexes with two corpora lutea in either ovary; (2) different sexes with a single corpus luteum in each ovary; (3) same sex with a corpus luteum in each ovary; (4) different sexes

with a corpus luteum in each ovary; (5) same sex with two corpora lutea in either ovary; (6) same sex with a single corpus luteum in either ovary. The possible occurrence of any one or all of the first three of these combinations is completely ignored by Dawson, who must have realized that such cases convincingly refute the claim that the right ovary alone supplies boys, and the left alone supplies girls. Instances of the fourth combination are apparently explained by him as being the few exceptions to "usual and normal unilateral ovulation." Instances of the fifth and sixth combinations are of value in confirmation of the theory only if the corpora lutea are demonstrated and the sex of the children known.

A careful study of the examples given by Dawson reveals but nine cases in this group of uncomplicated intrauterine pregnancies. Eight of these are single pregnancies, while the ninth falls into Group 5 of the double ovum twin combinations. In but three of the cases of single pregnancies is the presence of a right-sided corpus luteum in association with a male child demonstrated, while in the other two cases of male children the location of the corpus luteum is inferred. In the other three single pregnancies he attempts to show the left-sided origin of female children, but in only one of them is the presence of the corpus luteum actually demonstrated. The case of twin pregnancy is cited twice in the book (Tufnell's case, pp. 63 and 134) and would be acceptable, were it not for the fact that the sex of one child is not given.

Group B (Chapter IX).—Cases of extrauterine pregnancy usually terminate, spontaneously or by operation, at such an early period that the sex of the fœtus cannot be discerned and, therefore, most cases given in the literature cannot be accepted in proof of the theory. Some of the cases cited by Dawson fail in their purpose because of this defect. Forty-nine of his cases of extrauterine pregnancy given cannot be accepted as conclusive proof because in none of them is the actual presence of the corpus luteum demonstrated. The evidence advanced that the tube involved in an ectopic gestation indicates that the corpus luteum of pregnancy is in the corresponding ovary cannot be accepted in view of the acknowledged frequency of the so-called migration of the ovum. None of the cases cited in this group meets both the requirements essential to prove the theory.

Group C (Chapter X).—It would seem that those cases of pregnancy following the removal of one ovary, which are advanced by Dawson in this chapter, would prove conclusively the first premise of his theory. Seventeen such instances, four of the pregnancies being in one woman, are cited. One of the lot, being a tubal pregnancy, is open to the objections applying to Group B. Other reviewers of this book have based adverse criticism, according to Dawson, upon instances of children of both sexes being born after the removal of an ovary, as well as upon instances of boys being born after a right oophorectomy or girls being born after the left ovary had been removed. Dawson replies in answer to such criticism: "In these few exceptional cases who shall say some true ovarian tissue had not been left behind? or that there was no accessory ovarian tissue?" This argument is equally as effective in criticism of the cases cited by Dawson as in criticism of the cases adduced by his reviewers.

Group D (Chapter XI).—Instances of pregnancies in one horn of abnormal uteri should logically be placed in Group A along with those of intrauterine pregnancies, but, inasmuch as Dawson groups such cases separately, the cases given in this chapter will be considered separately. A total of 16 such cases, including seven repeated pregnancies, are cited as examples in favor of the theory. In 12 of these, including the repeated pregnancies, the location of the corpus luteum is not given, but is inferred from the horn or half of the uterus containing the pregnancy. This is the same method he used to determine the location of the corpus luteum in the cases of extrauterine pregnancy, and, as stated above, cannot be considered accurate because of the possibility of migration of the ovum. In two cases the location of the corpus luteum is again inferred from its absence in the only ovary examined. In another case the sex of the child is not stated, while the last case is given only by the title and not described. For those reasons, none of the cases cited in this chapter can be accepted.

This criticism of the examples given by Dawson is rather severe, for it shows that but four of his examples, a very small percentage of the total, are acceptable in proof of his theory. It is made, however, for the reason that any clinical argument against his theory must be based upon cases similar to those used by him and at the same time free from the objections that might make them liable to such criticism.

At the suggestion of Dr. Williams, the records of some 17,500 deliveries occurring in the Obstetrical Clinic of The Johns Hopkins Hospital from September, 1896, to March, 1918, were searched for suitable cases by which the principal theory advanced by Dawson could be tested. All those cases in which the location of the corpus luteum was actually demonstrated at Cæsarean section, at laparotomy for therapeutic abortion, at laparotomy within two weeks after delivery, or at post-mortem examination, and in which there was no question as to the sex of the child, were tabulated. While observations made at Cæsarean sections had frequently shown that male children were not always derived from the right ovary, and that female children were not always derived from the left ovary, the results obtained in Table I were rather surprising.

In all, 75 suitable observations were made on 70 women, five women each having two pregnancies. It is remarkable that the corpus luteum was found to be in the right ovary in 38 of the cases, and in the left ovary in 37 of the cases: an equal division. In 68 per cent, or in 26, of the cases in which the corpus luteum was located in the right ovary the child was male, while in the remaining 32 per cent, or 12 cases, the child was female. On the other hand, in 57 per cent, or in 21, of the cases in which the corpus luteum was located in the left ovary the child was male, while in the remaining 43 per cent, or in 16, of these cases the child was female. When we analyze the 75 cases from the standpoint of sex the result is more striking. In our series there were 47 male and 28 female children; 63 per cent and 37 per cent respectively.

For the 47 males the corpus luteum was found in the right ovary in 26, or 55 per cent, and in the left ovary in 21, or 45 per cent; while for the 28 females the corpus luteum was found in the right ovary in 12, or 43 per cent, and in the left ovary in 16, or 57 per cent.

From these figures it is evident that Dawson's theory cannot be correct, and, considering that the majority of the children in this series of cases are male, it is also clear that babies of either sex result in about equal numbers from the fertilization of an ovum from either ovary. Furthermore, one is led to say that clinical evidence shows that the determination of sex is probably not due to any factor present in the unfertilized ovum.

It is not considered necessary to quote in detail the histories of all the cases, but the five instances of repeated pregnancies in the same women are worthy of special consideration.

Pregnancies of Rachel J.—J. H. H. 5687. Delivered by conservative Cæsarean section on December 18, 1912, of a female child at term. Corpus luteum observed in the left ovary. J. H. H. 7027. Again delivered by conservative Cæsarean section on March 29, 1915, of a female child at term. Corpus luteum again observed in the left ovary.

Pregnancies of Seala F.—J. H. H. 6549. Delivered by conservative Cæsarean section on April 24, 1914, of a female child at term. Corpus luteum observed in the left ovary. J. H. H. 8955. Again delivered by conservative Cæsarean section on December 10, 1917, of a female child at term. Corpus luteum again observed in the left ovary.

Pregnancies of Mary L.— J. H. H. 7122. Delivered by conservative Cæsarean section on March 24, 1915, of a male child at term. Corpus luteum observed in the right ovary. J. H. H. 8666. Again delivered by conservative Cæsarean section on July 15, 1917, of a male child at term. Corpus luteum again observed in the right ovary.

Pregnancies of Minnie F.—J. H. H. 7291. Delivered by conservative Cæsarean section on July 2, 1915, of a male child at term. Corpus luteum observed in the right ovary. J. H. H. 8537. Again delivered by conservative Cæsarean section on May 12, 1917, of a male child at term. Corpus luteum again observed in the right ovary.

Pregnancies of Delia D.—J. H. H. 7276. Delivered by conservative Cæsarean section on July 1, 1915, of a female child at the ninth lunar month of gestation. Corpus luteum observed in the right ovary. J. H. H. 8242. Again delivered by conservative Cæsarean section on December 14, 1916, of a female child at term. Corpus luteum observed in the left ovary.

The first eight of these pregnancies seem to uphold Dawson's theory. The last woman, however, had two pregnancies resulting in females with the corpus luteum of the first pregnancy on the right side and that of the second pregnancy on the left. These two pregnancies, therefore, completely contradict the conclusion, which might be based upon the first eight pregnancies, that "the essential factor in the causation of sex" is connected with the supplying ovary.

In addition to these 75 observations, one instance of double ovum twin pregnancy was noted, in which a single corpus luteum only was demonstrated.

Pregnancy of Barbara D.—J. H. H. 8131. The patient, who was pregnant for the fourth time, died from eclampsia before delivery. Autopsy (4896) showed that the uterus contained a double ovum twin pregnancy of about nine lunar months' duration. The twins, both female, were definitely double ovum in origin; the placentæ being attached to opposite sides of the uterus and two complete sets of membranes being demonstrated. But only one corpus luteum of pregnancy could be found on macroscopical or microscopical examination of the ovaries (Obstet. Path., C. W. 1479), and that was in the right ovary.

If any inference can be drawn from a single case, this is offered as evidence against the left-sided origin of female children.

In view of the evidence afforded above of the failure of Dawson's theory concerning the predominating influence of the ovary in the causation of sex in beings, it hardly seems necessary to take notice of conditions in domestic animals. Furthermore, in criticizing the work of Doncaster, Dawson discounts any such proof in favor of his theory, as follows: "We have, however, no evidence that what occurs in the polytocous animals . . . . must equally apply to monotocous woman."

Being based upon one false premise it is evident that Dawson's rules for the prediction of sex cannot be accurate; but, for the sake of making this criticism more destructive, the second premise will also be shown to be fallacious.

The second premise upon which Dawson bases his rules is that the ovaries ovulate alternately. It has been supposed, but never proven, that this is the case. Dawson, in attempting to prove it, reviews the literature upon the subject and, without making any contribution thereto, takes the supposition for granted. This premise is, therefore, based upon questionable evidence. In addition, he states in explanation of the greater number of male births: ". . . . so that more ova are produced by the large right or male ovary than by the opposite or smaller left ovary." One is tempted to ask how more ova can come from the right ovary, other than in multiple pregnancies, if this ovary ovulates alternately and, therefore, just as frequently as the left. The argument advanced to prove the alternating action of the ovaries hardly deserves comment, for it is based mainly upon evidence afforded by symptoms at the time of menstruation, which, because of its subjective nature, cannot be considered trustworthy.

With the first premise false and the second based upon uncertain evidence, Dawson's rules for the determination of the sex of the unborn child cannot be accurate. In spite of this, however, and especially as Dawson claims success in 97 per cent of all attempts, it seems best that his rules should be applied to a group of cases.

In their most simple form these rules are: First, as menstruation is usually accepted as a sign of ovulation, any woman who menstruates normally every 28 days will ovulate 13 times yearly. Second, as the ovaries normally and usually ovulate alternately and unilaterally, ova will be discharged at alternate months from opposite ovaries. If, therefore, the date of the birth of a full-term child is known, and, consequently, the month determined in which its ovary functionated according to the rule, by proper calculation the sex of a child resulting from impregnation in any subsequent menstrual period can be foretold.

This simple formula advanced by Dawson was applied to all pregnancies in the women who furnished the basis for Table I,

TABLE I

Name of patient	House service number	Pregnancy: Order	Pregnancy: Duration	Date of delivery	Male children Corpus luteum: Right	Male children Corpus luteum: Left	Female children Corpus luteum: Right	Female children Corpus luteum: Left	Pathological numbers: Autopsy	Pathological numbers: Service
CÆSAREAN SECTIONS										
Annie J.	1420	3d	Term	Mar. 2 03	+	..	..	..	..	C. W. 585½
Rachel J.	5687	3d	Term	Dec. 18 12	..	..	..	+	..	..
	7027	4th	Term	Mar. 29 15	..	..	..	+	..	..
Clara J.	5709	1st	9 mos.	Nov. 30 12	+	..	..	..	3825	C. W. 1216
Florence S.	6184	1st	Term	Sept. 1 13	+	..	..	..	..	..
Evelyn Y.	6281	1st	7 mos.	Nov. 3 13	..	..	..	+	..	..
Dora S.	6313	1st	Term	Dec. 3 13	+	..	..	..	..	..
Seala F.	6549	7th	Term	Apr. 21 14	..	..	..	+	..	..
	8955	8th	Term	Dec. 10 17	..	..	..	+	..	..
Emma C.	6847	2d	Term	Oct. 31 14	..	+	..	..	..	C. W. 1331
Hattie J.	6893	3d	Term	Jan. 3 15	..	+	..	..	..	..
Carrie S.	6971	2d	Term	Jan. 6 15	..	+	..	..	..	..
Annie H.	7072	1st	Term	Feb. 27 15	+	..	..	..	..	C. W. 1366
Mary L.	7122	1st	Term	Mar. 24 15	+	..	..	..	..	..
	8666	2d	Term	July 15 17	+	..	..	..	..	..
Henrietta R.	7145	5th	Term	Apr. 9 15	+	..	..	..	..	C. W. 1377
Minnie F.	7291	3d	Term	July 2 15	+	..	..	..	..	..
	8537	4th	Term	May 12 17	+	..	..	..	..	..
Delia D.	7276	2d	9 mos.	July 1 15	..	..	+	..	..	..
	8242	3d	Term	Dec. 14 16	..	..	..	+	..	..
Esther H.	7705	3d	Term	Apr. 8 16	..	+	..	..	..	C. W. 1457
Ruth S.	7928	1st	Term	June 22 16	..	+	..	..	..	..
Marcella H.	8137	3d	Term	Oct. 21 16	..	+	..	..	..	C. W. 1480
Eliza D.	8196	3d	Term	Nov. 21 16	..	+	..	..	..	..
Ida G.	8486	1st	Term	Apr. 10 17	..	+	..	..	..	..
Marie B.	8753	3d	Term	Aug. 28 17	+	..	..	..	..	..
Daisy J.	8820	3d	Term	Sept. 23 17	+	..	..	..	..	..
Suzie D.	8826	4th	Term	Oct. 16 17	+	..	..	..	5334	C. W. 1540
Rose F.	8861	1st	Term	Oct. 18 17	..	+	..	..	..	..
Mary F.	9008	7th	Term	Jan. 3 18	..	+	..	..	..	..
Marie L.	9083	2d	Term	Feb. 8 18	..	..	..	+	..	..
Edwina R.	9084	2d	Term	Feb. 15 18	..	..	..	+	..	..
Lula W.	9092	3d	6 mos.	Feb. 14 18	..	+	..	..	..	..
Lizzie L.	9115	2d	8 mos.	Feb. 15 18	+	..	..	..	..	..
ABDOMINAL THERAPEUTIC ABORTIONS										
Bessie H.	6926	5th	4 mos.	Dec. 12 14	..	+	..	..	..	..
Wanda Z.	7870	6th	4 mos.	May 31 16	..	..	..	+	..	C. W. 1466
Alice L.	8717	?	4 mos.	Aug. 10 17	..	..	+	..	..	C. W. 1533
Christina G.	8986	?	3 mos.	Dec. 22 17	..	..	+	..	..	..
EXPLORATORY LAPAROTOMIES										
Elsie R.	5386	5th	Term	Apr. 30 12	+ (operated and died 2 weeks post partum)				3730	C. W. 1147
Florence W.	6694	4th	Term	Aug. 17 14	(op. 2 weeks postpartum)		+	..	..	C. W. 1314
Genieve G. W.	7570	3d	Term	Dec. 1 15	+ (operated at delivery)		..	..	..	C. W. 1433
Tenie O.	7692	9th	Term	Feb. 9 16	(operated at delivery)		+	..	..	C. W. 1450
AUTOPSIES										
Emma P.	9	1st	Term	Oct. 28 96	+	(died 2 days postpartum)			Lost	C. W. 505
Margaret B.	27	6th	Term	Feb. 16 97	+	(died 5 days postpartum)			912	..
Anna Y.	372	?	Term	Feb. 10 99	+	(died 26 days postpartum)			1304	C. W. 549
Eliza C.	460	13th	Term	July 10 99	(died 1 day postpartum)		+	..	1389	C. W. 550
Gussie H.	866	?	7 mos.	Apr. 15 01	(died 1 day postpartum)		..	+	1715	..
Eliza D.	1040	11th	Term	Jan. 15 02	(died at delivery)			+	1850	C. W. 583
Mary S.	1177	1st	7 mos.	May 29 02	(died 2 hrs. postpartum)		+	..	1934	C. W. 597
Elizabeth F.	1297	9th	Term	Oct. 5 02	..	+ (died few hrs. postpartum)			2004	..
Eleanor J.	2158	1st	Term	July 5 05	(died 4 days postpartum)		+	..	2566	..
Annie H.	2568	6th	Term	May 3 06	(died at delivery)		+	..	2718	..
May H.	2610	1st	Term	June 21 56	(died few hrs. postpartum)		+	..	2737	..
Mary F.	2828	3d	6 mos.	Nov. 11 06	..	+ (died 34 days postpartum)			2813	..
Rosetta B.	4116	2d	Term	Nov. 10 09	+	(died 5 days postpartum)			3294	..
Nora D.	4155	1st	Term	Oct. 26 09	+	(died 5 days postpartum)			3288	..
Mary S.	4203	3d	Term	Nov. 29 09	+	(died 3 days postpartum)			3303	C. W. 1030
Margaret F.	4205	11th	Term	Dec. 3 09	(died 5 hours postpartum)		+		3305	C. W. 1031
Hallie G.	4346	1st	Term	Mar. 18 10	+	(died 4 days postpartum)			3356	..
Georgie P.	5250	1st	Term	Feb. 23 12	..	+ (died 3 days postpartum)			3697	..
Annie C.	5394	1st	Term	May 5 12	..	+ (died 5 days postpartum)			3726	..
Margaret S.	5911	1st	Term	Mar. 30 13	+	(died 4 days postpartum)			3900	..
Mary M.	6093	1st	9 mos.	July 11 13	(died 3 days postpartum)			+	3963	..
Ruth B.	6730	9th	Term	Aug. 8 14	(died 4 days postpartum)		+	..	4170	..
Edna P.	7390	1st	9 mos.	Aug. 27 15	..	+ (died 10 days postpartum)			4446	..
Rose J.	7483	4th	7 mos.	Oct. 14 15	+	(died 17 days postpartum)			4490	..
Alverta M.	7606	?	Term	Dec. 25 15	..	+ (died 6 days postpartum)			4546	C. W. 1443
Ada G.	7902	1st	Term	June 5 19	(died at delivery)		+	..	4711	..
Elizabeth B.	8287	3d	Term	Jan. 25 17	..	+ (died 4 days postpartum)			5014	..
Lillian T.	8302	2d	Term	Jan. 27 17	(died 8 days postpartum)		+		5024	..
Vivian C.	8405	1st	3 mos.	Mar. 25 17	..	+	(died during pregnancy)		5077	C. W. 1506
Viola W.	8570	3d	Term	June 17 17	+	(died 2 days postpartum)			5184	C. W. 1519
Francis H.	8797½	7th	7 mos.	Sept. 30 17	(died 5 days postpartum)		+		5319	C. W. 1539
Lena L.	8844	5th	3 mos.	Oct. 26 17	..	+	(died during pregnancy)		5339	C. W. 1541
Kathleen S.	9000	2d	9 mos.	Jan. 4 18	(died 12 days postpartum)		+		5417	..
Totals.....75	75	Corpus luteum right....38			26	21	12	16		
		Corpus luteum left.....37			47		28			

TABLE II

Name of patient	Service number	Order of pregnancy	Date of delivery	Sex of child	Calculated sex	Confirms theory	Refutes theory
Annie J.	J. H. H. 751	2d	Oct. 2 00	Female	..	..	..
	J. H. H. 1420	3d	Mar. 2 03	Male	Male	+	..
Annie H.	J. H. H. 1657	5th	Jan. 14 04	Male	..	..	..
	J. H. H. 2568	6th	May 3 06	Female	Male	..	+
Esther H.	J. H. H. 2237	2d	Aug. 12 05	Female	..	..	..
	J. H. H. 7705	3d	Apr. 8 16	Male	Female	..	+
Rosetta B.	J. H. H 2739	1st	Dec. 4 06	Male	..	..	..
	J. H. H. 4116	2d	Nov. 10 09	Male	Male	+	..
Margaret F.	J. H. H. 2900	10th	Feb. 20 07	Female	..	..	..
	J. H. H. 4205	11th	Dec. 3 09	Female	Male	..	+
Rachel J.	J. H. H. 5687	3d	Dec. 18 12	Female	..	..	..
	J. H. H. 7027	4th	Mar. 29 15	Female	Female	+	..
Seala F.	J. H. H. 6549	7th	Apr. 21 14	Female	..	..	..
	J. H. H. 8955	8th	Dec. 10 17	Female	Male	..	+
Lillian T.	J. H. H. 6864	1st	Nov. 6 14	Male	..	..	..
	J. H. H. 8302	2d	Jan. 27 17	Female	Female	+	..
Mary L.	J. H. H. 7112	1st	Mar. 24 15	Male	..	..	..
	J. H. H. 8666	2d	July 15 17	Male	Male	+	..
Edwina R.	J. H. H. 7971	1st	Aug. 8 15	Male	..	..	..
	J. H. H. 9084	2d	Feb. 15 18	Female	Female	+	..
Elizabeth B.	O. O. S. 3965	1st	Oct. 23 08	Female	..	..	..
	O. O. S. 4527	2d	Jan. 22 10	Male	Male	+	..
	J. H. H. 8287	3d	Jan. 25 17	Male	Female	..	+
Viola W.	O. O. S. 5287	1st	Oct. 12 11	Female	..	..	..
	O. O. S. 5996	2d	May 24 13	Female	Female	+	..
	J. H. H. 8570	3d	June 17 17	Male	Male	+	..
Carrie S.	J. H. H. 6283	1st	Nov. 18 13	Male	..	..	..
	J. H. H. 6971	2d	Jan. 6 15	Male	Female	..	+
	J. H. H. 8332	3d	Jan. 29 17	Female	Male	..	+
Ruth B.	O. O. S. 1515	6th	Mar. 10 02	Male	..	..	..
	O. O. S. 2927	7th	May 27 06	Male	Male	+	..
	O. O. S. 5031	8th	Mar. 12 11	Male	Female	..	+
	J. H. H. 6730	9th	Aug. 8 14	Female	Female	+	..
Henrietta R.	J. H. H. 2728	2d	Nov. 27 06	Male	..	..	..
	J. H. H. 3894	3d	May 10 09	Female	Male	..	+
	J. H. H. 5398	4th	July 23 12	Male	Female	..	+
	J. H. H. 7145	5th	Apr. 9 15	Male	Female	..	+
Hattie J.	J. H. H. 5142	1st	Dec. 18 11	Male	..	..	..
	J. H. H. 6156	2d	Aug. 12 13	Male	Female	..	+
	J. H. H. 6893	3d	Jan. 3 15	Male	Male	+	..
	J. H. H. 8303	4th	Dec. 27 16	Male	Female	..	+
Susie D.	J. H. H. 5354	1st	June 18 12	Male	..	..	..
	J. H. H. 6975	2d	Jan. 7 15	Female	Female	+	..
	J. H. H. 7835	3d	Apr. 29 16	Female	Female	+	..
	J. H. H. 8826	4th	Oct. 16 17	Male	Female	..	+
Minnie F.	J. H. H. 5898	1st	Mar. 22 13	Female	..	..	..
	J. H. H. 6460	2d	Feb. 25 14	Female	Female	+	..
	J. H. H. 7291	3d	July 2 15	Male	Female	..	+
	J. H. H. 8537	4th	May 12 17	Male	Female	..	+
Elsie R.	J. H. H. 2657	1st	July 26 06	Male	..	..	..
	O. O. S. 3734	2d	Apr. 6 08	Male	Male	+	..
	J. H. H. 3972	3d	June 3 09	Male	Female	..	+
	O. O. S. 4922	4th	Dec. 17 10	Female	Female	+	..
	J. H. H. 5386	5th	Apr. 30 12	Male	Male	+	..
Florence W.	O. O. S. 4252	1st	June 9 09	Female	..	..	..
	O. O. S. 4780	2d	Aug. 20 10	Female	Male	..	+
	J. H. H. 5393	3d	May 4 12	Female	Female	+	..
	J. H. H. 6694	4th	Aug. 17 14	Female	Male	..	+
	O. O. S. 7306	5th	Jan. 31 16	Female	Female	+	..
	O. O. S. 7962	6th	May 27 17	Male	Female	..	+
Totals.....20	60			60	40	20	20

employing only repeated full-term pregnancies occurring in women whose menstrual cycle was 28 days. Twenty women were found who had had 60 pregnancies. In 40 of these the sex of the children subsequent to the first child was calculated and compared with the sex of the child as noted at delivery. The results of this comparison are given in Table II and show that Dawson's rule was accurate in but 50 per cent, or in 20, of the cases: a percentage that is in keeping with the laws of probability and chance.

CONCLUSIONS

The conclusions reached from this consideration of Dawson's theory that the supplying ovary is the essential factor in the causation of sex, and from the application of his rules to a group of cases free of any objections are:

1. The supplying ovary has no influence upon the sex of the child.

2. Male and female children result in about equal numbers from the fertilization of ova from either ovary.

3. The causation of sex is probably not due to any factor in the unfertilized ovum.

4. The "chromosome theory" must be considered the only explanation of the causation of sex at present acceptable.

5. The sex of an unborn child cannot be foretold, nor can either sex be produced at will, by any rules known at present.

REFERENCES

References to the authorities quoted in this article and to the other literature upon this subject will be found in the footnotes in Dawson's book, "The Causation of Sex in Man," Hoeber, 1917, and in J. Whitridge Williams' "Obstetrics," IV Ed., Appleton, 1917, pp. 170-172.

THE PISTON ACTION OF THE VERTEBRAL COLUMN DEVELOPED IN CERTAIN TYPES OF CRANIAL FRACTURES

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The casualties developed upon a modern aviation field occasionally present conditions of great scientific interest. Neither time nor occasion would warrant a discussion or even a tabulation of the types afforded in this interesting and highly important service. A brief note upon the following case, observed at a former post, would seem to be worthy of record:

An airship, of the usual training type, made an ordinary "take off." This was promptly (indeed prematurely) followed by a "zoom" at such an acute angle that, lacking the needful velocity, the ship crashed to earth. The pilot (second cockpit) was practically uninjured; the mechanic (forward cockpit) was killed.

For the present occasion, the only injury to be discussed was that sustained by the cranium. Bleeding from the nose and ears, in moderate quantity, was in evidence; the vertical diameter of the head (in proportion to the general contour) seemed somewhat shortened. There were no surface lesions of head, face, or neck, of pertinent significance. When the scalp was removed a curvilinear fracture beginning at the left frontal eminence was found; this tended inferiorly and disappeared, beneath the peeled scalp, at approximately the lateral margin of the left supraorbital ridge. When the calvarium was lifted, the brain surface was found to be engorged, with numerous subdural hemorrhages; the brain mass was perceptibly less firm than usual, and markedly flattened out when laid upon the table. On removal it was noted that the spinal cord had been severed at approximately its junction with the medulla. The distal stump lay posteriorly upon the occipital bone.

The frontal fracture (*vid. ante*) was found to have entered the left anterior fossa at *A*, to have proceeded posteriorly and medially, dividing and subdividing until, having circumscribed the foramen magnum, it ceased to be visible or palpable at *B* in the right occipital fossa.

It is a matter of regret that obedience to service regulation regarding autopsies forbade a thorough orientation of the cranial base, the face, and the vertebral column. It is highly probable that further careful study would have exhibited matters of substantial scientific value.

All cranial fractures are of surgical interest, but the feature that makes this basal fracture worthy of record is the fact that the entire basal mass, circumscribed by the fracture, was driven superiorly within the cranial cavity to an extent varying at different points, from $\frac{1}{8}$" to $\frac{3}{4}$". The figure fails to exhibit the notably serrated margins; nor would time permit an attempt to portray the damage executed by numerous lanceolate spicules and massive fragments that lacerated and lifted the dura in radiating planes.

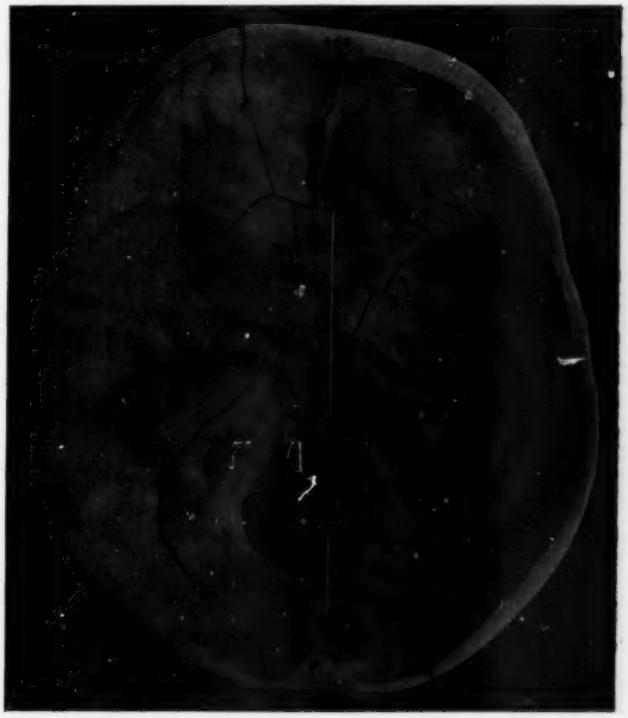

FIG. 1.—Exhibiting tracing of basal fracture of skull. In order to portray the extension of the fracture down to the foramen magnum, the skull has been considerably tilted. (Secured through the courtesy of Prof. Augustus G. Pohlman, professor of anatomy, Medical Department, St. Louis University.)

The question might well be raised, What caused this enormous trauma of the cranial base? As noted above, the surface markings of scalp, face, and neck were devoid of significance.

"Fracture by contrecoup"[1] would doubtless have sufficed as an explanation in the past, not so to-day. The following seems to be most worthy of credence:

The unchecked "nose-down" fall of an airship is highly destructive, owing to the great disproportion that exists between the heavy motor and the light fuselage. The terrific impact usually telescopes the former into the latter. It is well known that the forward cockpit is more liable to destruction than the second. The victim, in this instance, seated in the forward cockpit sustained the crushing drive of the motor upon his vertex (transmitted either through the anterior rim of the forward cockpit, or more probably through the instrument board). The tremendous upward thrust of the motor on the vertex was met by the counterthrust of the fuselage and equipment, plus the weight of the two men, strapped in their seats. It is fairly obvious that the vertebral column, acting as a piston, drove before it the cranial base, to invade the cranial cavity, as above noted.

[1] This eighteenth century hypothesis, of the French, has been discredited in the light of studies upon cranial elasticity and cranial meridians by Aran, von Bruns, Messner, Hermann, von Wahl, Hilton, Félizet, and Cushing. Of particular interest is the observation of Hilton, regarding one anteroposterior and two transverse osseous buttress-arches, in relation to well-known areas of structural weakness.

Had this fracture been developed by the more usual types of vertical impact it might have been anticipated that a fair conformation to the structural configuration of the cranium (*conf.* footnote) would follow. But even the strong counterthrust of the vertebral column exerted upon the cranial base would hardly suffice to account for the fracture variations exhibited. If, however, consideration be given to the manifest probability that a marked flexion of the head upon the thorax was developed, thus permitting a substantial supplementary counterthrust to be exerted through the chin and the temporomandibular articulations, orientation of the variant fissures will prove less difficult.

This piston action of the vertebral column merits consideration in the differential study of cranial traumata, developed by severe vertical impact. But it is an open question whether this piston action of the vertebral column, in explanation of certain types of cranial fracture, has received the consideration that it merits. Well digested evidence, based upon further experimental, operative, and autopsy procedures, should prove valuable.

It but remains to add that in all probability similar basal fractures, developed by similar factors, in similar environment, will arise more or less constantly in the Aviation Service, and transform an abstract surgical problem into one of vitally practical significance.

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